

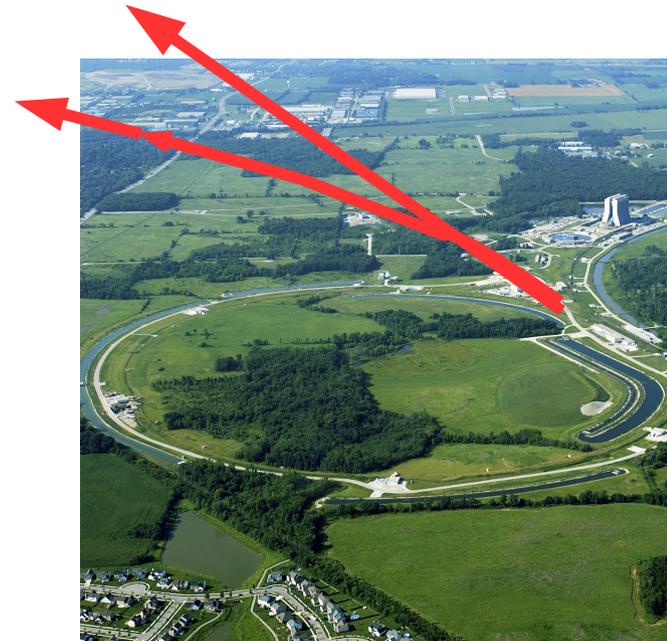
# Toward a Highly Realistic Main Injector Simulation for Project-X



Eric Stern  
and  
CPA/CD Group

MINOS and  
NovA neutrinos  
to Soudan mine  
and Ash River  
(MN)

LBNE neutrinos  
to DUSEL (SD)





# At 2 MW Project-X Intensities, beam losses must be understood and eliminated

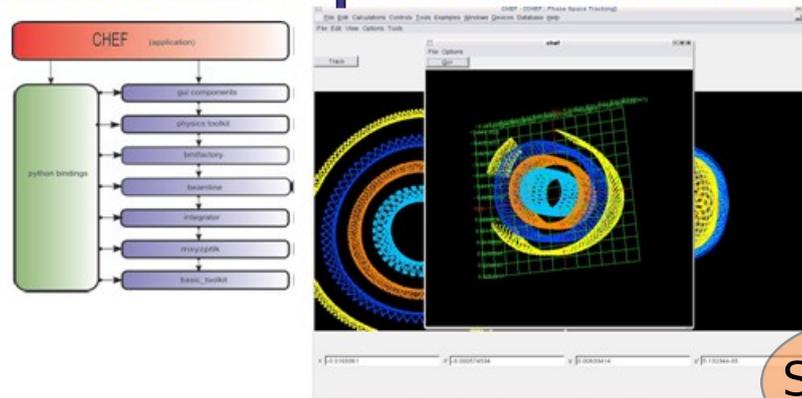
Beam loss drivers that can possibly be simulated

- Higher order multipoles in magnets
- Space charge
- Apertures and restrictions
- Impedance

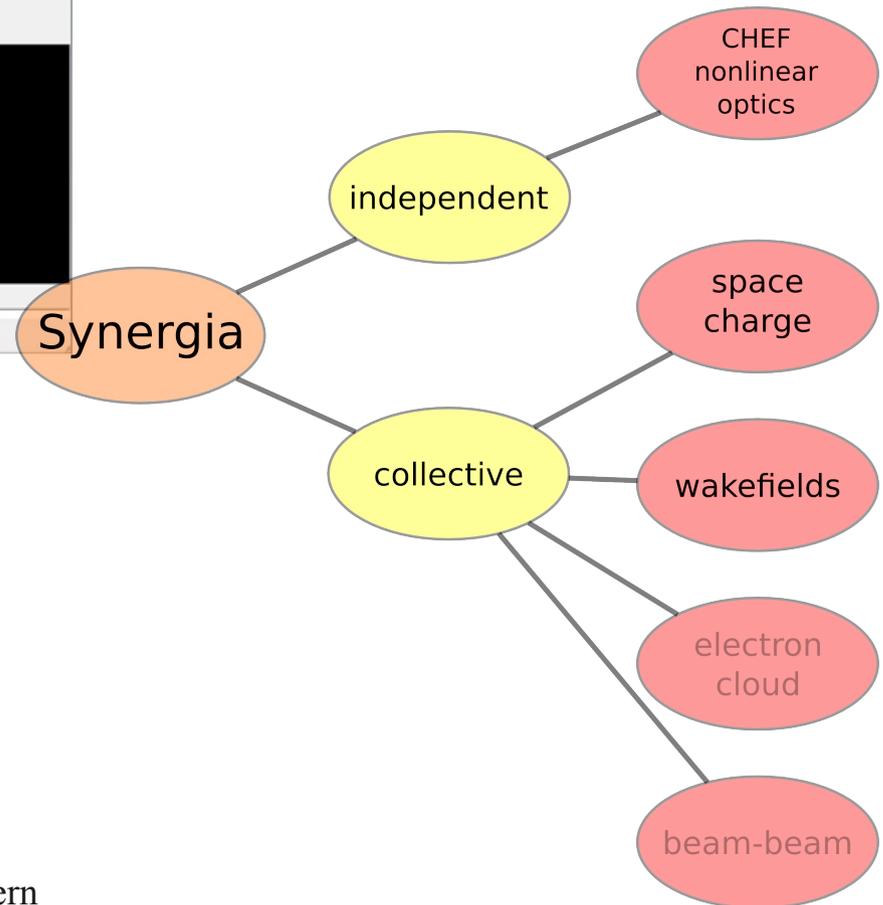


## CHEF single particle nonlinear tracking

### Collaborative Hierarchical Expandable Framework



Synergia collective effects framework driver



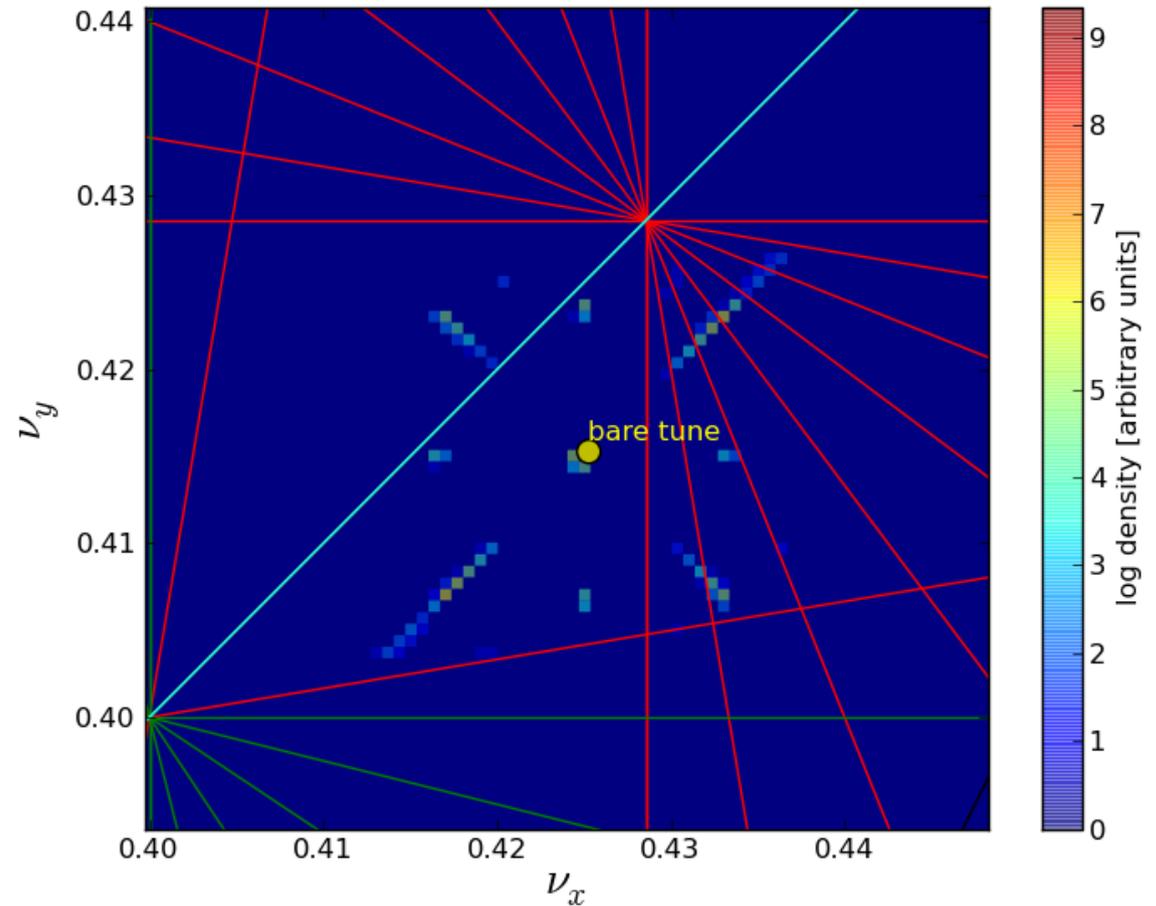


# Cute nonlinear effects in the base lattice

Main Injector lattice has sextupoles, synchrotron oscillations and a large longitudinal bucket.

No space charge  
3<sup>rd</sup> order map propagation

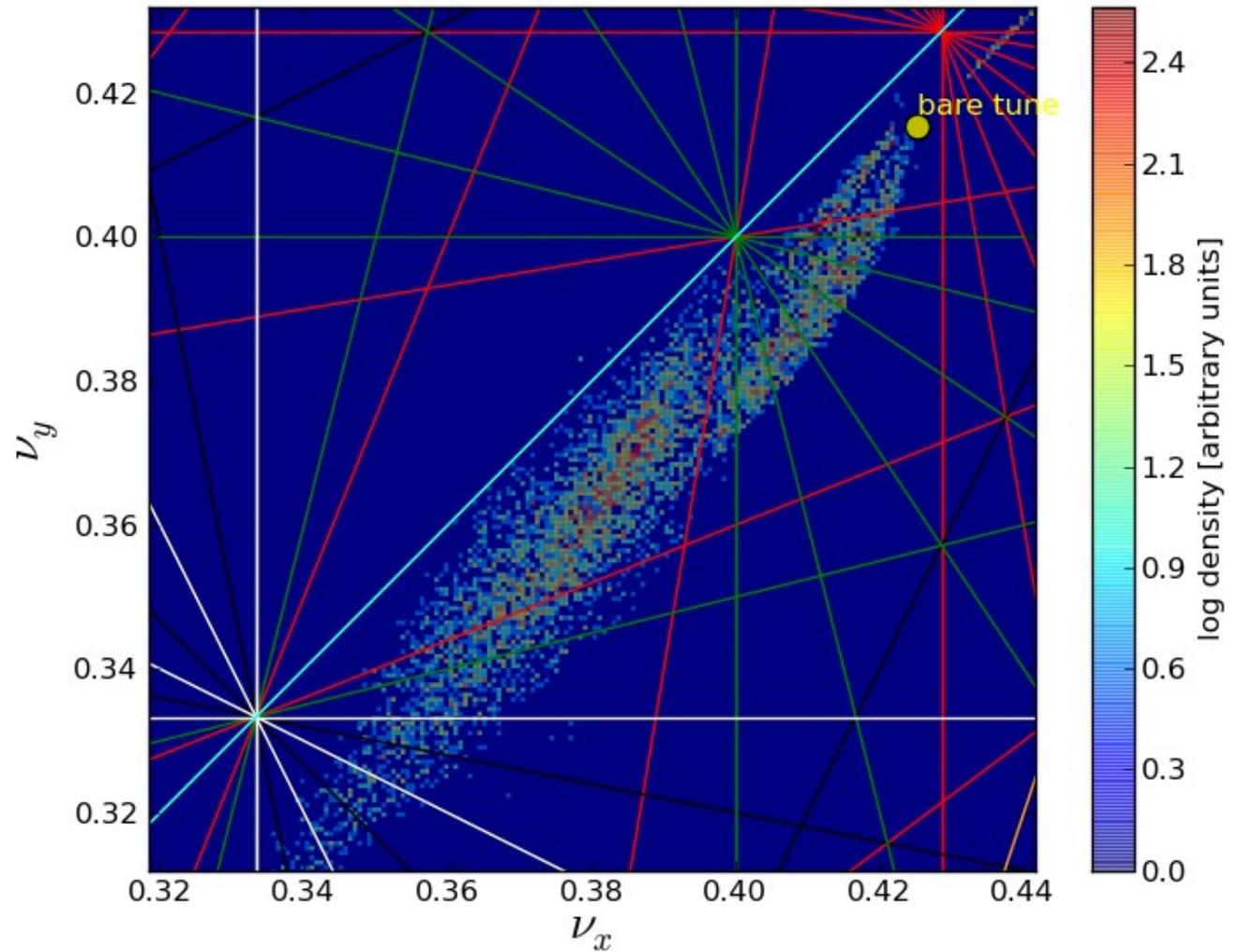
In practice, this is obscured by other effects



# Turning on space charge



Beam intensity  $1.1 \times 10^{11}$





Magnet Test Facility measured coefficients  $b_k, a_k$

$$\text{such that } B_y + i B_x = \sum_k \frac{(b_k + i a_k)}{R_0^k} (x + i y)^k$$

$k$  up to 6 (tetradecapole) for most dipoles and quadrupoles

$R_0$  is the radius of the measuring coil (1 inch)

Mean and standard deviation for most magnets  
compiled and summarized in tables by A. Drozhdin and  
B. Brown

# Higher order multipoles (continued)

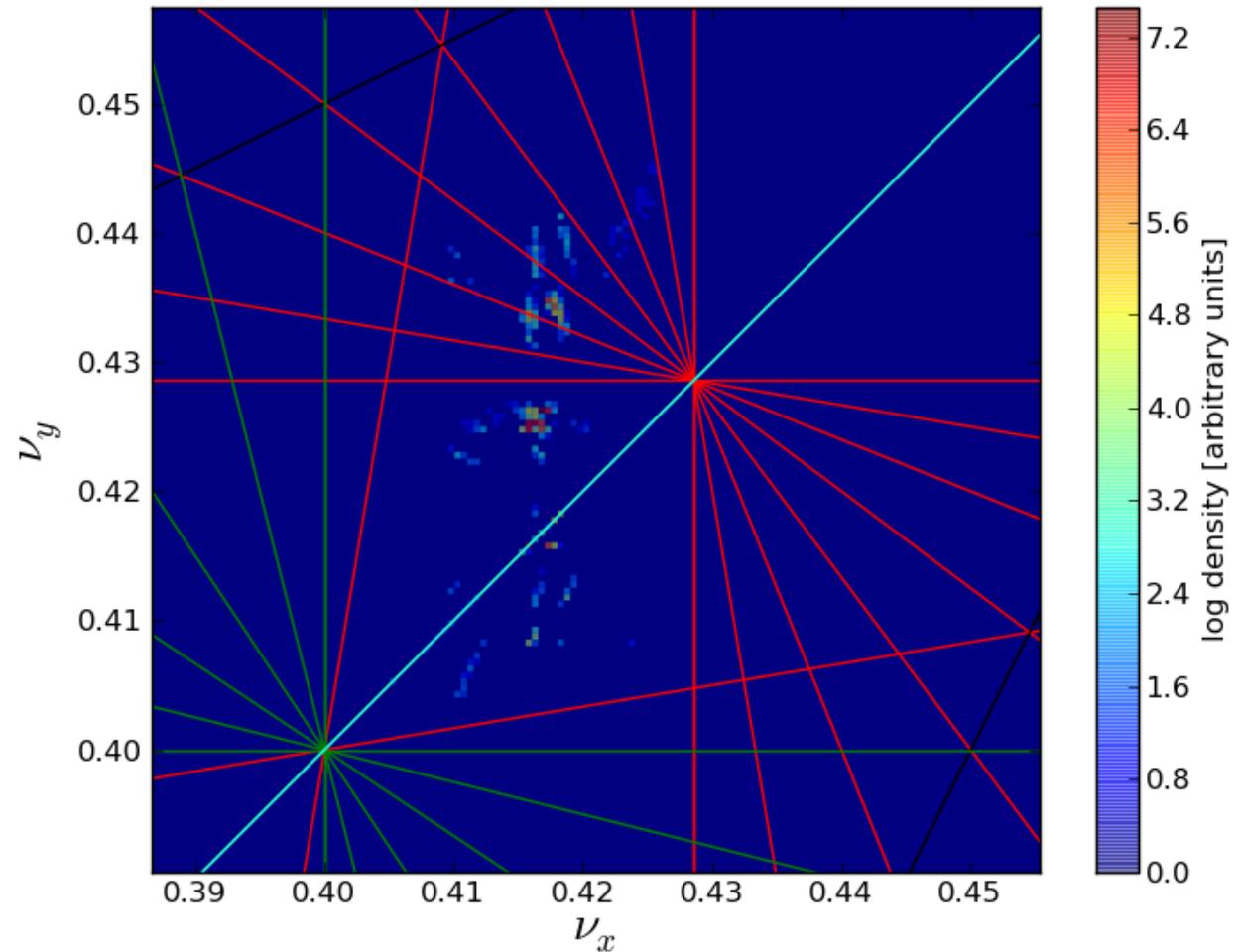


To run, generate random multipoles, insert as a thinpole object within existing magnets.

Results of one run 2000 turns, no space charge

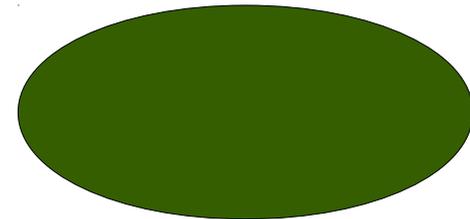
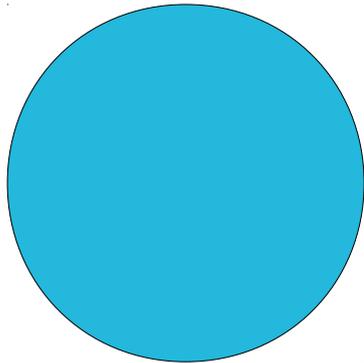
Currently, only dipole magnet multipoles active.

Quadrupole components within dipole magnets change the tune. The machine must compensate for this?



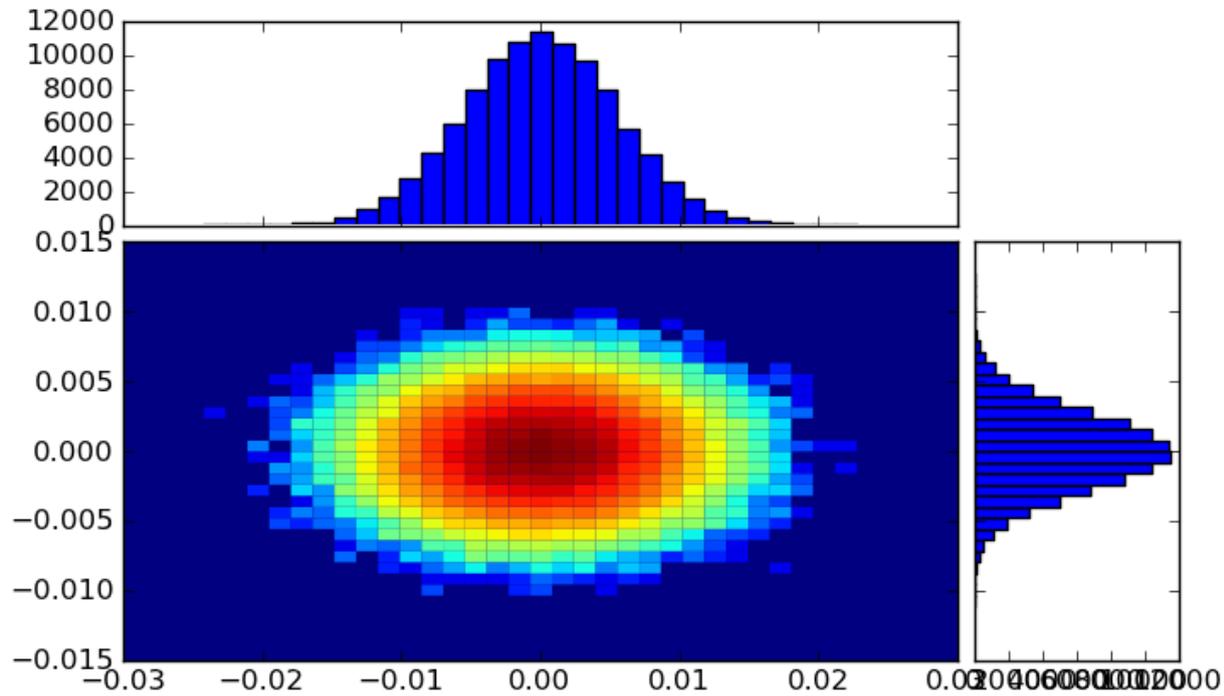


Three basic apertures implemented so far.  
More can be easily added.

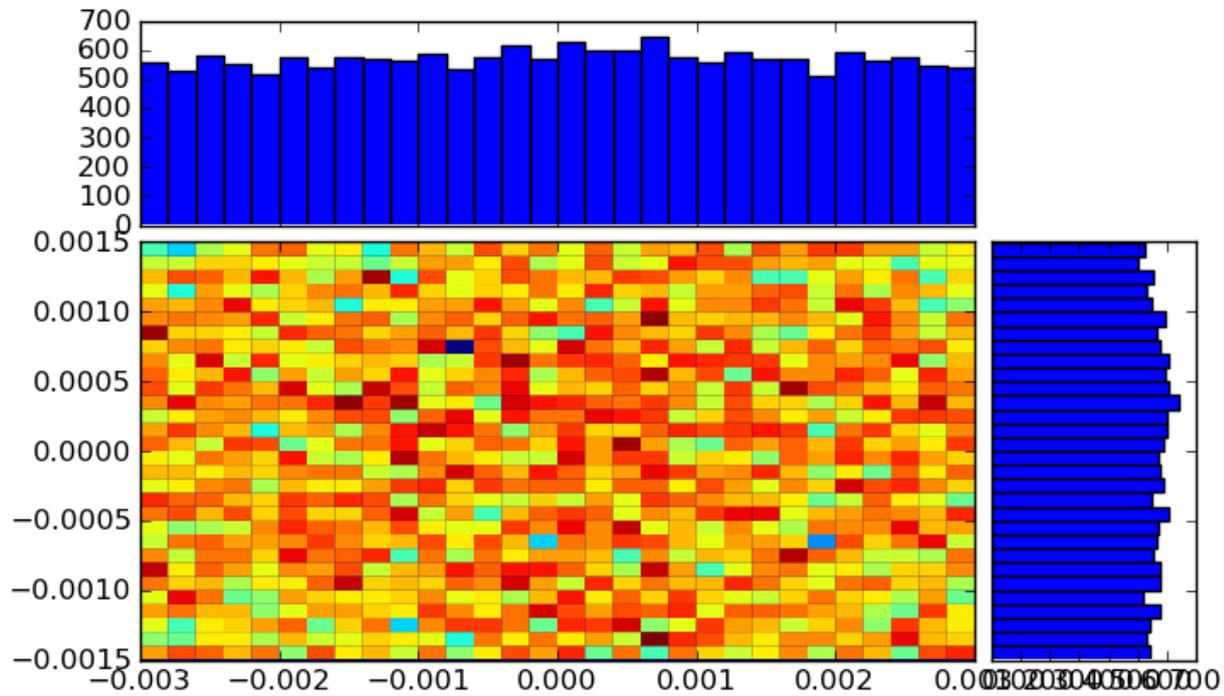


The dimensions of a particular aperture object may be specified. Apertures associated with sections of the beamline.

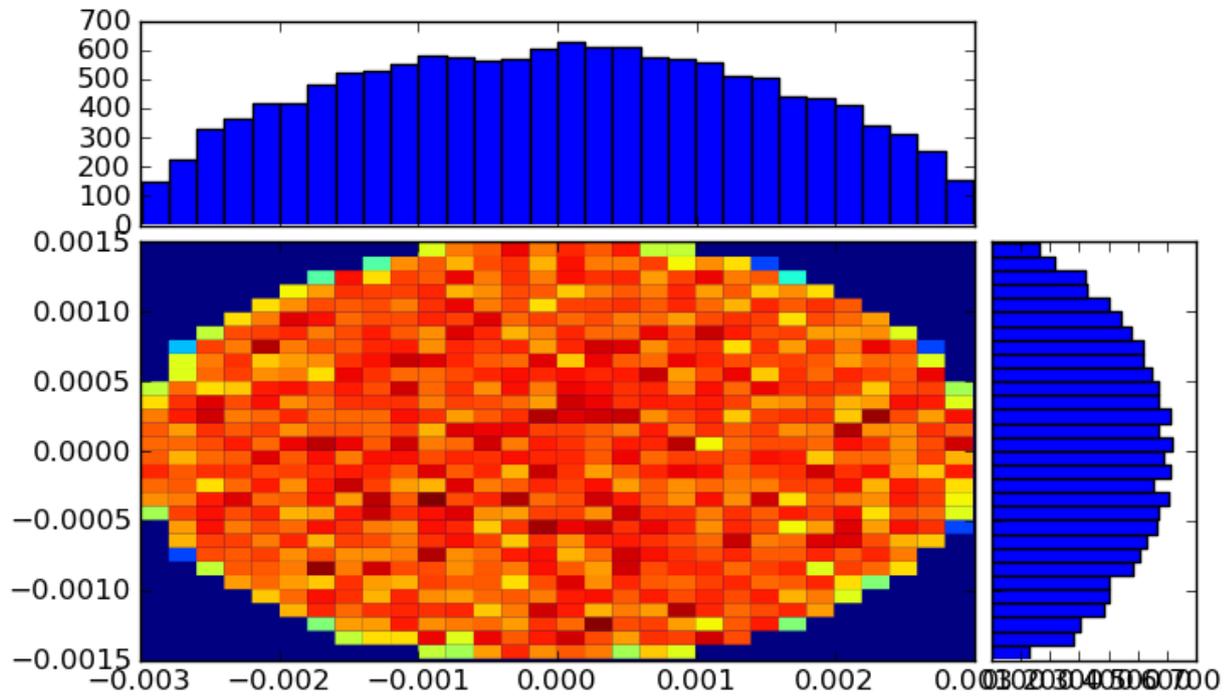
# Test of Aperture Input



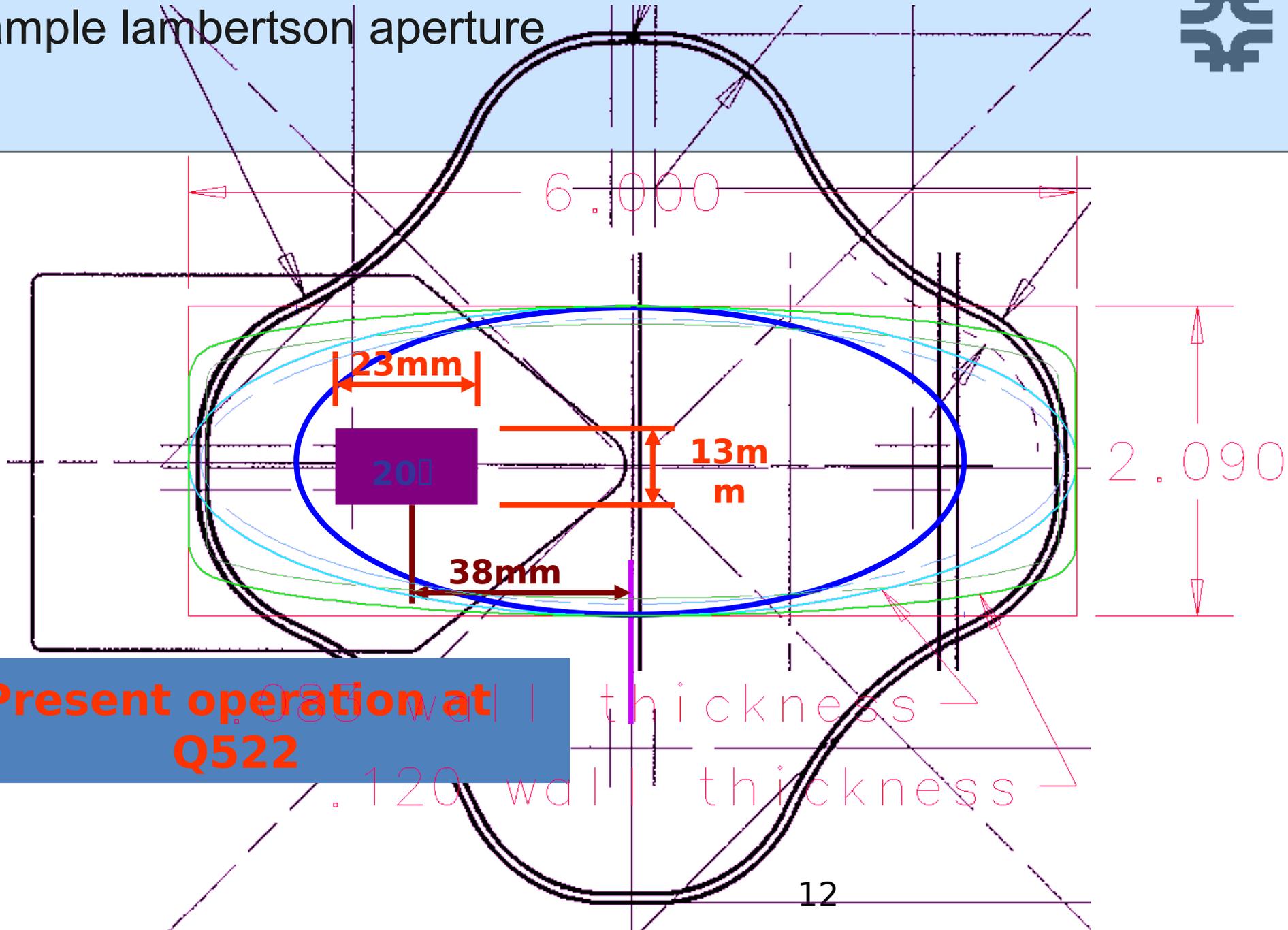
# Square Aperture Output



# Elliptical Aperture Output



# Example lambertson aperture



**Present operation at Q522**



# First runs with apertures and multipoles

Model the lambertson aperture in the general vicinity of the Q522 location.



Running with one set of generated multipoles and no space charge, 3 particles out of 500K particles were lost in 2000 turns.



Complete multipole implementation

Add more apertures

Run more particles with more turns

We are developing and incrementally improving the tools to faithfully model the Main Injector for Project X running conditions.